Please type a plus sign (+) inside this box → +

PTO/SB/21 (08-00)
Approval for use through 10/31/2002. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	09/848,648
Filing Date	May 3, 2001
First Named Inventor	Davey, Kenneth John
Group Art Unit	2855
Examiner Name	Max H. Noori
Attorney Docket Number	90001
Total Number of Pages in This Submission	

ENCLOSURES *(check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment / Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☒ Certified Copy of Priority Document(s)
- ☐ Response to Missing Parts/ Incomplete Application
  - ☐ Response to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Assignment Papers *(for an Application)*
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) ________
- ☐ After Allowance Communication to Group
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to Group *(Appeal Notice, Brief, Reply Brief)*
- ☐ Proprietary Information
- ☐ Status Letter
- ☐ Other Enclosure(s) *(please identify below):*

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm *or* Individual name	Jacqueline E.Hartt Allen, Dyer, Doppelt, Milbrath & Gilchrist, P.A.
Signature	Jacqueline Hartt
Date	February 2, 2004

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, Washington, D.C. 20231 on this date: February 2, 2004

Typed or printed name	Edward Bradley		
Signature	Edward Bradley	Date	February 2, 2004

Patent Office
Canberra

I, JONNE YABSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 7266 for a patent by STRUCTURAL MONITORING SYSTEMS LIMITED as filed on 03 May 2000.

WITNESS my hand this
Fifteenth day of December 2003

J R Yabsley

JONNE YABSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

APPLICANT: STRUCTURAL MONITORING SYSTEMS LIMITED

FILING DATE: 3 May 2000

AUSTRALIA

PATENTS ACT 1990

PROVISIONAL SPECIFICATION

FOR THE INVENTION ENTITLED:

"SYSTEM AND METHOD FOR CONTINUOUS MONITORING OF THE STRUCTURAL INTEGRITY OF A COMPONENT OR STRUCTURE"

The invention is described in the following statement:-

SYSTEM AND METHOD FOR CONTINUOUS MONITORING OF THE STRUCTURAL INTEGRITY OF A COMPONENT OR STRUCTURE

The present invention relates to a system and method for use in the continuous monitoring of the structural integrity of a component or structure and in particular for monitoring the integrity of a structure or component to provide an early indication of an impending fault or crack and the location of the source of the fault or crack.

A very important function of design and maintenance engineers is to monitor for, locate and assess the initial location of surface faults or cracks that develop in structures or components under static or dynamic loads and subsequently determine the likely propagation path of the fault or crack. Examples where the monitoring of surface faults and cracks may be critical include on wing sections of aircraft; turbine blades on jet engines, the hull of a ship and the boiler of a nuclear power plant. Often, the monitoring is by visual inspection only. However it will be appreciated that when faults or cracks initially develop they are often extremely small and imperceptible to the eye. Alternately, the faults or cracks may arise in structures or components that are physically difficult or indeed impossible to access.

International Application No PCT/AU94/00325 (WO 94/27130) discloses a monitoring apparatus that can be used to detect faults or cracks in the surface of a structure. The monitoring apparatus described includes a substantially constant vacuum source connected in series with a high impedance device that in turn is connect with one or more cavities formed on the surface of a structure. A differential pressure transducer is connected across the high impedance device to monitor the vacuum state of the cavity. A pressure differential transducer monitors the change in vacuum condition between the cavities and the constant vacuum source. Accordingly if there is a change in vacuum condition in the cavities which can arise from the formation and propagation of a crack the change is detected by the transducer.

Embodiments of the present device and method are suited for use with the monitoring apparatus described in the aforementioned International application.

It is an object of the present invention to provide a system and method for continuous monitoring of the structural integrity of a structure or component.

For ease of description from herein, including the claims, the term "structure" is used as a reference to a structure or component.

According to the present invention there is provided a system for use in the continuous monitoring of the structural integrity of a structure, said system including at least:

an elastomeric sensor pad having a first structure engaging surface and an opposite surface, said first structure engaging surface provided with a set of at least one first channels which, when said first structure engaging surface is sealingly engaged with said structure, form a corresponding set of at least one first cavities;

first fluid communication means for providing fluid communication between said set of at least one first channels and a constant vacuum source; and

isolation means for isolating each of said first cavities from fluid communication with said constant vacuum source.

Preferably said system further includes means for monitoring for a variation in the vacuum condition between the constant vacuum source and said first cavities.

In one embodiment, said sensor pad further includes:

a set of at least one second channels formed on said first structure engaging surface which, when said first surface is sealingly engaged with said structure, form a corresponding set of at least one second cavities;

said second channels intersperse with said first channels; and,

a second fluid communication means for providing fluid communication between said second cavities and an atmosphere or environment at a pressure different to said constant vacuum source.

Preferably said first communication means includes a third channel provided in said first surface, said third channel being in fluid communication with each of said first channels

and with said constant vacuum source.

In an alternate embodiment said first fluid communication means includes a plurality of conduits, one of each providing fluid communication between respective first channels and the constant vacuum source.

Preferably said second communication means includes a fourth channel provided in the first surface, said fourth channel being in fluid communication with each of said second channels and said atmosphere or environment.

In an alternate embodiment said second fluid communication means comprises an opening in each of said first channels that provides fluid communication through the pad to said atmosphere environment.

Preferably said isolation means includes means for applying force to said pad at respective locations above each or selected ones of said channels, to seal said first and/or second channels against the structure.

In one embodiment said pad further includes a set of fifth channels interleaved with said first or second channels formed on said first surface of said pad in the region of said elastomeric portion.

Preferably said fifth channels are in fluid communication with said third channel.

Preferably said isolating means is adapted to individually and sequentially isolate said cavities so that progressively all of said cavities are isolated from said vacuum source.

Preferably said isolating means is programmable so that the sequence of isolating said cavities can be varied.

In one embodiment, said means for applying force includes a plurality of actuators supported on or in said elastomeric portion above each of said lengths for applying force

to said resiliently portion to sealingly deform said corresponding channel against the structure.

Preferably said actuators are electrically, magnetically, hydraulically, pneumatically, or mechanically operated.

According to the present invention there is also provided a method for continuously monitoring the integrity of a structure, said method including at least the steps of:

providing a sensor pad having a first structure engaging surface and opposite surface, the first surface provided with a set of at least one first channels;

sealingly engaging said first surface of the sensor pad with the structure so that said channels together with the structure form a corresponding set of first cavities;

coupling said first cavities to a constant vacuum source;

monitoring for a change in vacuum condition between said cavities and said constant vacuum source; and

isolating each of said first cavities from said constant vacuum source.

In one embodiment, the step of isolating each of said first cavities includes venting said first cavities to the atmosphere or surrounding environment.

According to the present invention there is also provided a method for continuously monitoring the integrity of a structure, said method including at least the steps of:

providing a sensor pad having a first structure engaging surface and an opposite surface, the first surface provided with a set of at least first channels and a set of at least one second channels, said first channels isolated from and interspersed with said second channels;

sealingly engaging said first surface of the sensor pad to the structure so that said channels together with the structure form a corresponding set of first and second cavities;

coupling said first cavities to a constant vacuum source;

coupling said second cavities to an atmosphere or environment at a different pressure or vacuum condition to said constant vacuum source;

monitoring for a change the vacuum condition between said first cavities and said vacuum source; and

isolating each of said first cavities from said constant vacuum source.

Preferably said step of isolating said cavities includes individually and sequentially isolating said cavities so that progressively all of said cavities are isolated from said vacuum source.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a plan view of a first structure engaging surface of a sensor pad incorporated in the system and method for continuously monitoring the integrity of a structure;

Figure 2 shows a section through the sensor pad depicted in Figure 1;

Figure 3 is a plan view of a second surface of a sensor pad;

Figure 4 is a section view through an elastomeric portion of the sensor pad depicting the operation of the isolation means incorporated in the system;

Figure 5 is a plan view from the bottom of the sensor pad shown in Figure 4;

Figure 6 is a plan view of a second embodiment of the sensor pad;

Figure 7 is a schematic representation of an embodiment of the isolation means incorporated in the device;

Figure 8 is a schematic representation of a further embodiment of the system; and

Figure 9 is a plan view of yet a further embodiment of the system.

As depicted in Figures 1 - 4 with particular reference to Figure 4, the system 10 for use in continuously monitoring the integrity of a structure 14 includes a sensor pad 16 having a first structure engaging surface 18 and a second opposite surface 20. The first surface 18 is provided with a set of first channels 22 and a set of second channels 24. The first channels 22 are isolated from and interspersed with the second channels 24. As shown in

Figures 2 and 4, when the surface 18 of the pad 16 is sealingly engaged to surface 12 of structure 14 the first channels 22 and second channels 24 together with the surface 12/structure 14 form respective sets of the first and second cavities 26 and 28. A first fluid communication means in the form of a third channel 30 and a conduit 32 (refer Figure 3) provides fluid communication between the first channels 22/first cavities 26 and a constant vacuum source (not shown). (Accordingly the channels 22/cavities 26, can be termed as "vacuum" channels/cavities.) A second fluid communication means in the form of a fourth channel 34 and conduit 36 provides fluid communication between the second channels 24/second cavities 28 and an atmosphere environment of a different pressure or vacuum condition to the constant vacuum source. (Thus the channels 24/cavities 28 can be termed as "atmospheric" channels/cavities.) Isolation means in the form of a plunger or probe 38 (see Figure 4) is included in the system 10 for individually isolating the first channels 22/first cavities 26 from the vacuum source. In this embodiment the entirety of the pad 16 is made of an elastomeric material.

The probe 38 in this embodiment pushes on the surface 20 of pad 16 to sealingly deform the portion of pad 16 over an underlying length of a channel 22/cavity 26. In this way, the channel 22/cavity 26 is isolated from communication with the channel 30 and conduit 32 and thus isolated from the vacuum source. As explained in greater detail below, the probe 38 can be moved or repositioned above and/or along the length of each of the channels 22/cavities 26 to individually isolate them from the vacuum source.

Various methods of use of the system 10 as depicted in Figures 1 - 4 will now be described.

In order to monitor for the creation and development of a fault or crack 40 in the structure 14, the pad 16 is sealingly engaged to the structure 14 with the surface 18 of the pad 16 in direct sealing contact with the surface 12 of the structure 14. The conduit 36 may be connected to an unimpeded constant vacuum source to aid sealing of the sensor pad 16 to the surface 12. Thereafter the conduit 36 is disconnected from the vacuum source and provides fluid communication between the surrounding atmosphere and the channels 24/cavities 28. Alternately, the conduit 36 can be connected to an environment at a

pressure different or vacuum condition to that of the constant vacuum source.

Next, the conduit 32 is connected to a monitoring apparatus of the type described in the aforementioned International Application No PCT/AU94/00325. However, initially, the impedance device shown in the monitoring apparatus is bypassed to assist in the sealing and installation of the pad 16. After installation, the bypass is removed so that the conduit 32 is in fluid communication with the constant vacuum source via a high-impedance fluid flow means. The monitoring apparatus includes a differential pressure transducer that is connected across the high-impedance fluid flow means so as to monitor any change in the vacuum condition between the vacuum source and the vacuum in the channels 22/cavities 26. If a crack or fault 40 (shown in Figure 2) were to develop in the structure 14 and open onto the surface 12 and propagate so as to form a fluid communication path between one of the channels 22/cavities 26 and an adjacent channel 24/cavity 28 there will be a change in the vacuum condition of the channel 22/cavity 26 in question. This change is detected by the monitoring apparatus thereby providing an indication as to the initial formation of the crack or fault 40.

However, this merely provides an indication that the crack or fault 40 exists somewhere within the area of the pad 16. To more specifically locate the position of the fault or crack 40 the isolating means, ie. probe 38 is applied to the surface 20 sequentially at points above each of the channels 22. The magnitude of the force applied by the probe 38 is sufficient to sealingly flatten the channel 22 against the structure 14 to thereby seal the corresponding cavity 26. If, upon applying this force, there is no change in the reading of the monitoring apparatus then the crack or fault 40 does not underlie or is not in fluid communication with that particular channel 22/cavity 26. However, when there is a change in the vacuum condition indicated by the monitoring apparatus upon the application of the force by the probe 38 then a portion of the crack or fault 40 is disposed beneath or otherwise in fluid communication with that particular channel 22/cavity 26.

The probe 38 can be in the form as depicted in Figure 4 so as to isolate only a single individual channel 22 at any one time. Alternately, the isolating means can be formed to sequentially isolate each of the channels 22 so as to progressively seal each and every one

of the channels 22.

A first position line of the crack or fault 40 corresponds with the centre line of the channel 22/cavity 26 which, by virtue of the above method, is determined as the one in which the fault or crack 40 traverses.

A second position line can be established by removing the pad 16, rotating the pad 16 by approximately 45° on its perpendicular axis and reinstalling it over the first position line and thereafter determining a second position line in the same manner as the first. The intersection point of the first and second position lines denotes the location of the fault or crack 40.

Further the isolating means, ie. probe 38, can be moved along a channel 22/cavity 26 to pinpoint where along that channel/cavity the fault or crack 40 intersects.

A prototype of the pad 16 in accordance with the embodiment as depicted in Figure 1 has been constructed and tested in which each channel 22 and 24 and its longitudinal walls have a width of 500 microns with a potential to locate faults and cracks down to 500 microns in length. However, it is envisaged that pads 16 having channels and adjacent walls of width of 250 microns or less can be produced to meet requirements of various applications.

In the above described method, the probe 38 is applied to the vacuum channels 22/cavities 26. However it should be understood that essentially the same effect can be achieved by applying the probe to the "atmospheric" channel 24/cavities 28. Clearly, if the probe 38 is applied to a portion of the pad 16 to seal an atmospheric channel 24/cavity 28 at a location between a crack 40 and the fourth channel 34 (and assuming that the crack 40 is also in fluid communication with an adjacent "vacuum" channel 22/recess 26) then the monitoring apparatus will indicate a change in the vacuum condition because there is now no leakage to the atmosphere.

In yet another method of use, the system 10 can be used to track the propagation of a fault

or crack 40 in the event that a fault or crack has been detected or is known to exist. In this method, the pad 16 is placed over the fault or crack at a location so that the crack extends from the footprint of the pad 16 and thus is in communication with the surrounding atmosphere. Also in this method, all of the cavities formed in the pad are coupled to a constant vacuum source via a high impedance. Thus for example looking at Figure 1, both channels 30 and 34 are coupled with the constant vacuum source. Alternately, the pad 16 can be constructed with only the channels 22 and 30. Assume that the fault or crack 40 extends from across the edge of the pad 16 but has not yet propagated to intersect the first of the channels 22. In this situation, the monitoring apparatus will not detect any change in vacuum condition thus indicating that the fault or crack has not propagated to the first of the channels 22. In time, if and when the fault or crack 40 propagates to the first of the channels 22, the monitoring apparatus will detect the change in vacuum condition. At this time, the intersected channel 22 can be isolated from the constant vacuum source by some form of isolating means. Optionally, if desired, once isolated the channel 22 can be totally decoupled from the channel 30 it may be vented to the atmosphere. This isolation/venting can occur automatically upon the detection of any change in the vacuum condition, or alternately only upon the detection of a predetermined variation in the vacuum condition.

In any event, once the first of the intersected channels 22 has been isolated and/or decoupled the monitoring apparatus returns to a steady state reading until the crack or fault 40 propagates so to intersect the next vacuum channel. In this way the propagation path of the crack can be recorded. Also, by running the isolating means along the vacuum channel upon the detection of the crack intersecting the channel the location of the intersection point of the crack 40 with the vacuum channel can be pinpointed thus allowing accurate depiction of the propagation path of the crack or fault 40.

A second embodiment of the pad 16a is depicted in Figure 6. The pad 16a includes first channels 22 extending at one end from a third channel 30 and, a fourth channel 34 as in the first embodiment of the pad 16 depicted in Figure 1. However pad 16a differs from pad 16 in that the second channels 24 which extend from the fourth channel 34 terminate at respective ends 42 which as spaced by a strip-like portion 44 from channel 30. In addition the pad 16a is provided with a set of fifth channels 46 that extend from the

channel 30 in the strip 44 and co-linear with respective channels 24. Distant ends 48 of the channels 46 are spaced from the ends 42 of respective co-linear channels 24 by a small element 50 of the pad 16a. As is apparent from Figure 5, the channels 50 are interleaved with the channels 22.

In this embodiment, the channels 50 merely provide a space or void to accommodate the material of the pad 16a when compressed by a probe 38 or other isolating means to seal an adjacent channel 22 in the regional area of the strip 44.

However, it is stressed that the provision of the strip 44 and the channels 50 is purely optional.

Figure 7 depicts a further embodiment of the system 10b in which the isolating means 38b is magnetically operated. Here, the isolation means 38b comprises a plurality of actuators 60 which are embedded in pad 16b. The actuators 60 are in the form of magnetic plungers. The isolation means 38b also includes a dynamic magnet 62 that is mounted in a support (not shown) so as to be capable of movement along the portion 48 above each of the actuators 60. The actuators 60 and magnet 62 are of the same magnetic pole. Accordingly by sliding the dynamic magnet 62 over a particular actuator 60, the actuator 60 is forced in a downward direction sealingly compressing the underlying channel 22/cavity 26. A programmable stepper motor (not shown) can be provided to control the motion and position of the dynamic magnet 62 so as to isolate the channels 22/cavities 26 in any desired sequence.

Figure 8 depicts a further embodiment of the system 10c. Here the system 10c includes a sensor pad 16c and an isolating means 38c. The sensor pad 16c is provided with only first (ie vacuum) channels 22. Further, the channel 30 is now replaced by a plurality of conduits 30c that provide fluid communication between the channels 22 and a constant vacuum source (not shown) which is in fluid communication with the isolating means 38c. Each of the conduits 30c is made from a resilient tube or at least a tube which includes a length of resilient material that passes through and is acted upon by the isolating means 38c. The isolating means 38c includes a cam shaft provided with a cam lobe for each of

the conduits 30c arranged so that when the cam shaft is rotated individual cam lobes can compress and seal the respective conduits 30c thereby isolating the corresponding channels 22/cavities 26 from the conduit vacuum source. This provides an alternate system for performing the method referred to hereinabove for monitoring or tracking the propagation of the fault or crack 40.

Of course, the isolating means 38c can, instead of being provided with a cam shaft, have other types of valves, switches or mechanisms for selectively shutting or sealing the conduits 30c. Further, as described above the system 10c can be constructed so as to only shut off a conduit 30c when the change in vacuum condition of corresponding channel 22/cavity 26 reaches a predetermined threshold level. At that time, in addition to isolating the channel 22/cavity 26 from the constant vacuum source it may vent the channel/cavity to the atmosphere.

It will also be appreciated that the pad 16c can be considered as equivalent to a pad having alternating first and second channels 22, 24 but where the second channels 24 are in constant fluid communication with the constant vacuum source.

Components of a further embodiment of the system 10d is illustrated in Figure 9. This figure depicts a pad 16d which differs from the pad 16 of Figure 1 by the inclusion of a second conduit 64 which is in communication with the channel 34 and a valve 66 which operates on both the conduit 36 and the conduit 64. To assist in the visualising of the location of the fault or crack 40, the conduit 64 is in fluid communication with a dye or other coloured liquid. In use, the valve 66 is initially set so as to open the conduit 36 but close conduit 64. Once a fault 40 has been detected the valve 66 is actuated to open the conduit 64 resulting in the dye or coloured liquid being drawn through the conduit 64 channel 36 and the channel or channels 24 that are in communication with the fault 40. The drawing of the dye or liquid arises as a result of a localised low pressure generated by the fault 40 forming a fluid communication path between the channels 24 and 22. As the dye or liquid is drawn into the channel 24 its flow will by and large cease at the fault 40 because the fault 40 will be very small and act as a restrictor tube. Provided the pad 16d is made from a translucent or transparent material the process of the dye or coloured liquid

can be followed to allow a visual indication as to the location of the fault.

Now that embodiments of the device and method for monitoring the condition of a surface have been described in detail it will be apparent to those skilled in the relevant arts that numerous modifications and variations may be made without departing from the basic inventive concepts. For example, the pad 16 is depicted as being of a rectangular configuration. However the pad can be made of any shape to accommodate or suit the application at hand. Also, the channels 22, 24, 30 and 34 are depicted as being on the surface 18 only of the pad 16. However similar channels can also be formed on the opposite surface 20 of the pad so that the pad 16 can simultaneously monitor the condition of the surface of adjacent adjoining structures. In this regard, the pad 16 can be formed as part of a bond between the structures and more particularly can be made from an elastomeric adhesive.

Embodiments are described in which the channels 22/cavities 26 are sealed by the application of a force either directly on the channels 22/cavities 26, (eg. Figure 4) or on conduits 30c (see Figure 8) in fluid communication with said channels and cavities. However in an alternate embodiment, the pad 16 can be provided with conduits of the type depicted in Figure 8 which, instead of being acted upon externally by a compressive force, can each be provided with an internal separately actuatable valve for opening or closing the fluid communication path with the vacuum source. It will be appreciated in such an embodiment (as with the embodiment depicted in Figure 8) there is no need for the pad 16 itself to be made from a resilient material because the opening and closing of the communication path between the channels 22/cavities 26 and the vacuum that draws outside of the pad 16 itself. Indeed, it is further envisaged that other embodiments can be constructed in which each of the channels 22 is provided with its own internal valve that can be separately controlled to open and close communication between the channel 22 and the channel 30.

All such modifications and variations together with others that would be obvious to a person of ordinary skill in the art are deemed to be within the scope of the present invention the nature of which is to be determined by the above description..

Dated this 3rd day of May 2000

STRUCTURAL MONITORING SYSTEMS LIMITED
By Its Patent Attorneys
GRIFFITH HACK

Fellows Institute of Patent and Trade Mark
Attorneys of Australia.

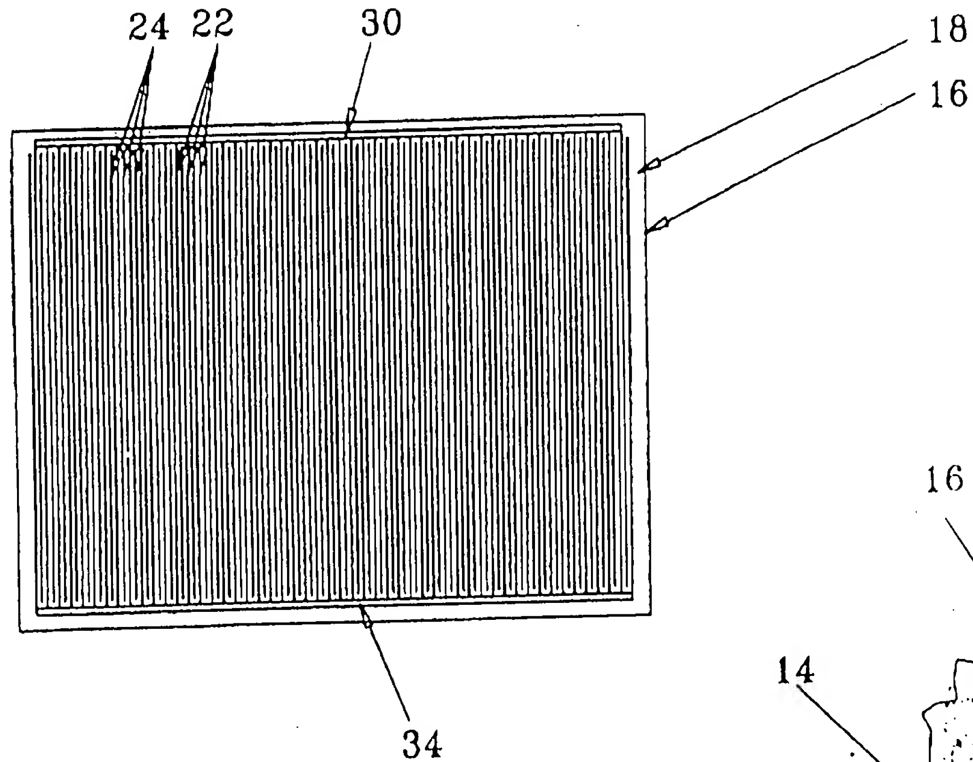

Fig. 1

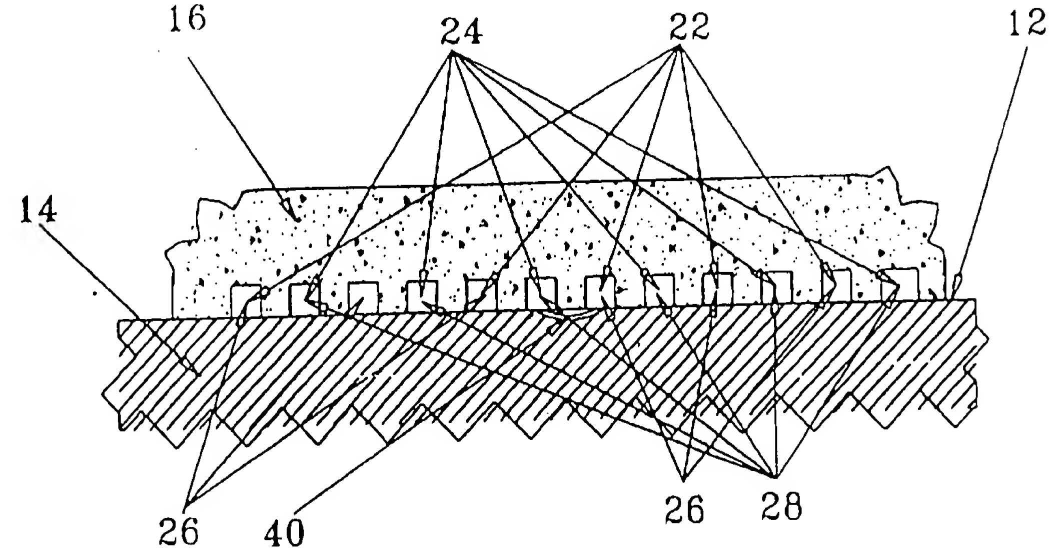

Fig. 2

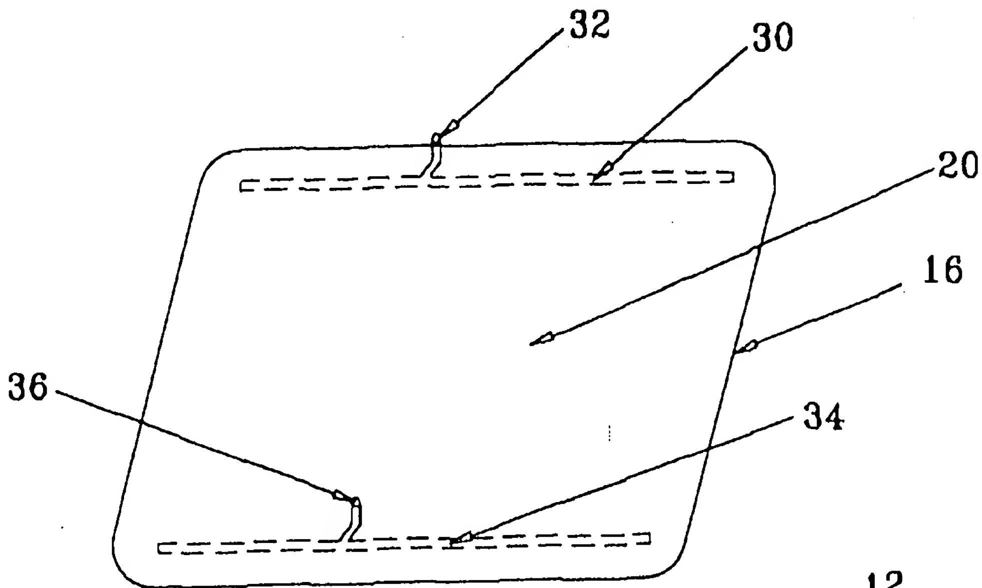

Fig. 3

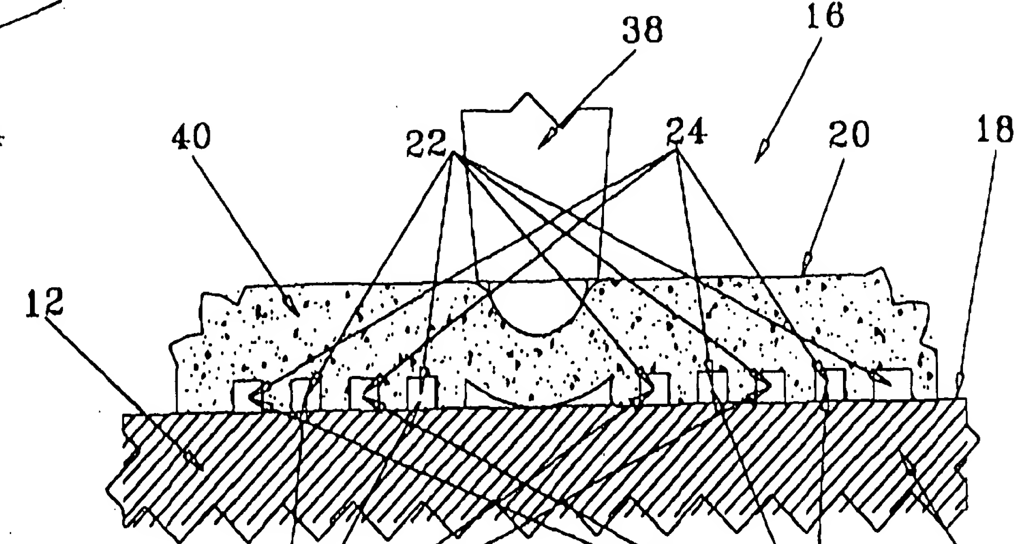

Fig. 4

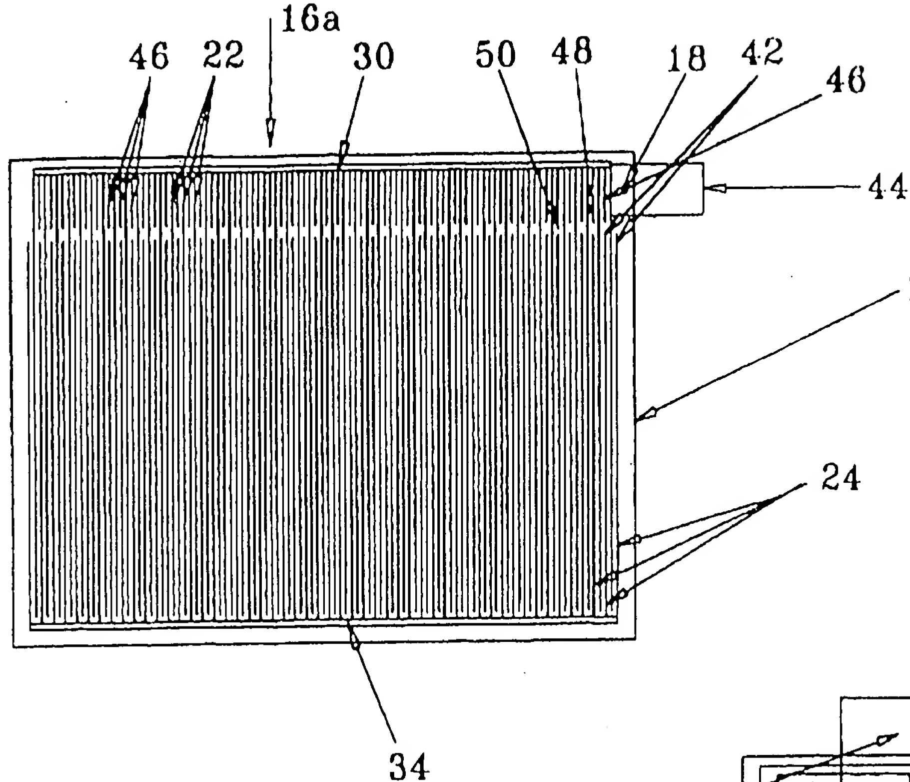

Fig. 6

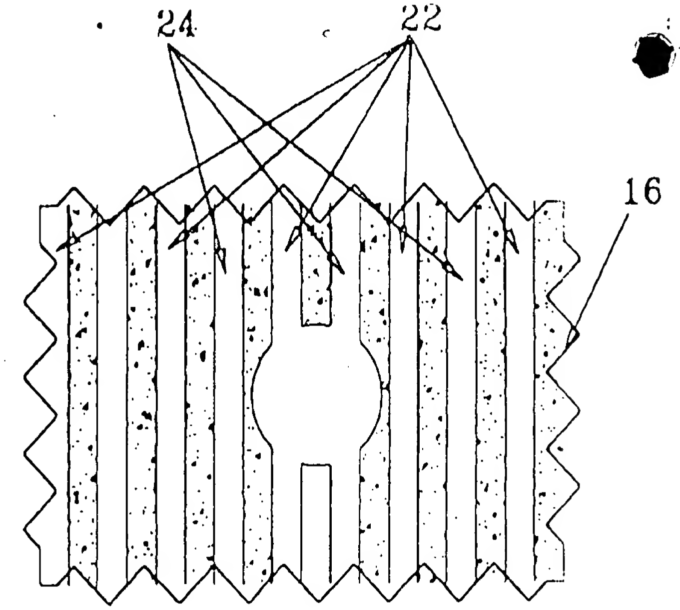

Fig. 5

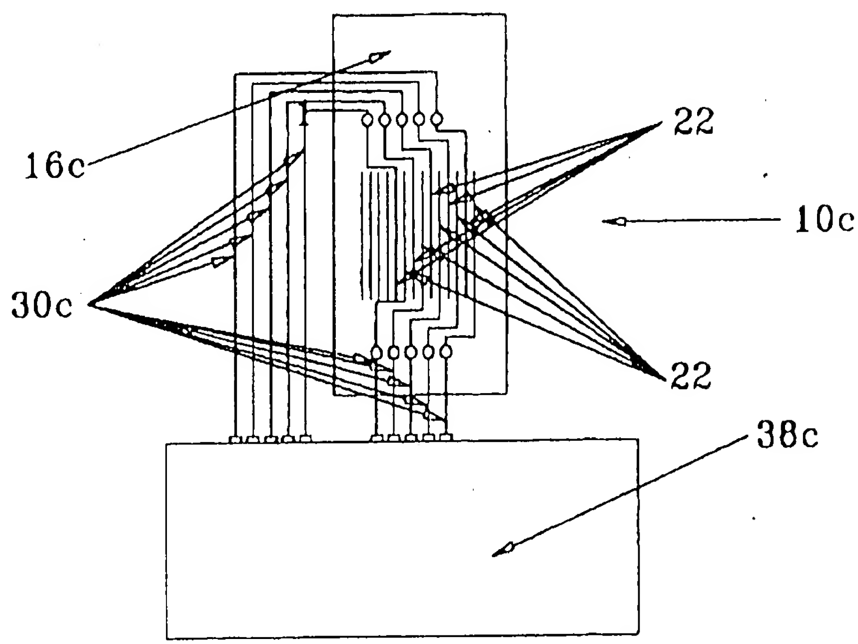

Fig. 8

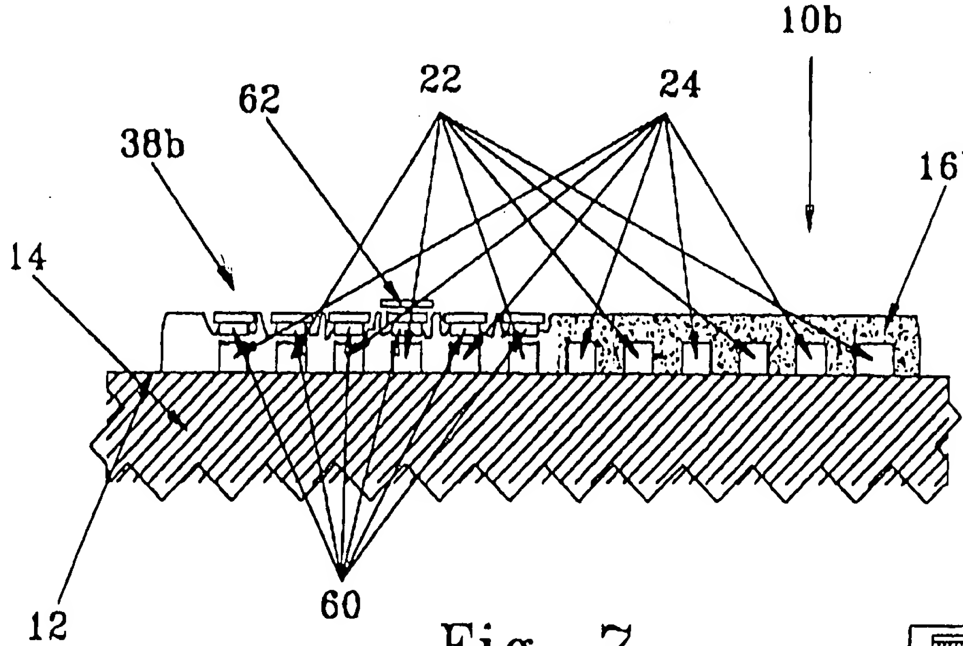

Fig. 7

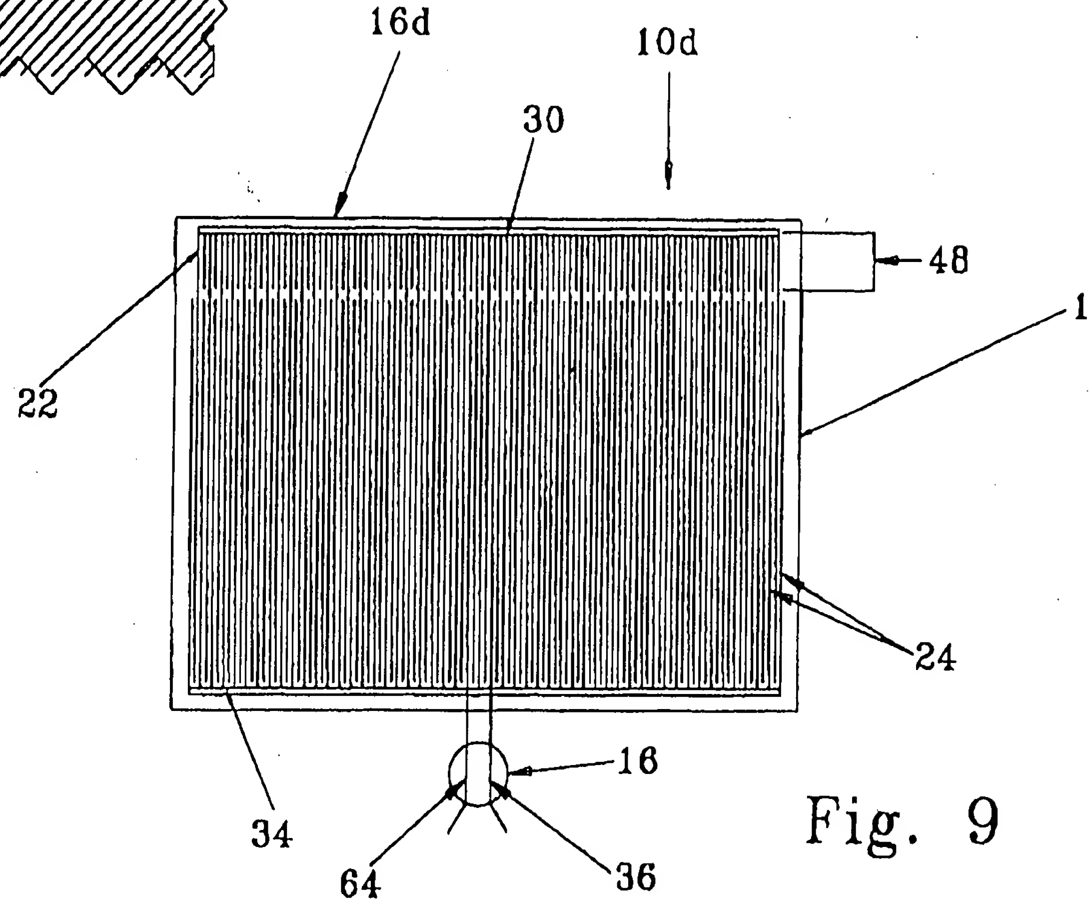

Fig. 9